# Micro-grid and Environmental Protection

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***Abstract*—The way of energy generation and utilization in modern society is changing rapidly. Micro-grid is emerging as an effective solution for solving the shortage problem of fossil fuels, realizing the flexible, large number and diversity of distributed renewable power supply, and reducing environment pollution. In this paper, the microgrid to the modern society is described in detail. And the microgrid is compare with the traditional grid. The significance of renewable energy for the micro-grid and the basic structure of renewable energy technology in detail are also explained. The microgrid benefits to environment through actual cases are fully discussed. And the possible harm of microgrid is also concerned. This paper may provide a helpful reference for researchers and students to obtain a brief understanding for the microgrid and its corresponding technologies.**

***Keywords*—micro-grid, environment, generation, renewable energy, energy storage battery system**

## I. Introduction

The way of energy generation and utilization in modern society is changing rapidly. The existing power system is facing the shortage of fossil fuels and environment pollution. On another hand, the proportion of renewable energy, such as solar and wind power, is increasing gradually. Distributed power supply has the advantages of small investment, environmental protection and high flexibility. But the randomness and fluctuation of distributed power supply are uncontrollable, and the large-scale application and access also bring great challenge and impact to the traditional power grid.

Micro-grid is emerging as an effective solution for these issues. Micro-grid is a small power generation and distribution system, which is composed of distributed power supply (renewable energy source), energy storage device, energy conversion device, load, monitoring and protection device. The introduction of micro-grid realizes the flexible, large number and diversity of distributed power supply. It can realize the active distribution network to realize the reliable supply of various load energy forms, which makes the transition from the traditional grid to the smart grid.

In this paper, the microgrid to the modern society is described in detail in Section II. And the microgrid is compare with the traditional grid for the environmental protection benefits which is in Section III. The significance of renewable energy for the micro-grid and the basic structure of renewable energy technology in detail are also explained, which is shown in Section IV. The discussion about renewable energy, such as solar energy and wind energy, are displayed in this section. The microgrid benefits to environment through actual cases are fully discussed in Section V. And the possible harm of microgrid is also concerned in Section VI. At last, we also talk about the future trends about the microgrid.

## II. Microgrids: A Hot Topic of Power System Concept in Recent Years

### A. The Basic Concept of Micro-grid

Micro-grid is a small power generation and distribution system which integrates distributed power supply, load, energy storage device, converter and monitoring and protection device [1]. With the help of the key technologies such as Operation Control and energy management, the micro-grid can be connected to the grid or operated in isolation, and the adverse influence of intermittent distributed power supply on the distribution network can be reduced.

Connecting distributed power supply to distribution network in the form of micro-grid can connect to the main grid. As a link between distribution network and distributed power supply, micro-grid makes distribution network not have to face the distributed power supply with different kinds, different attribution, large quantity and distributed access (even intermittent).

### B. Two Different Operational Modes of Microgrid

Grid-connected operation: Micro-grid can be connected to the main grid, which can be seen in Fig. 1. In grid-connected operation mode, the micro-grid can purchase power from the main grid, and supply the surplus power to the main grid [2]. In this mode, the micro-grid can achieve power interconnection with the main grid and have backup power and complementary energy functions, can provide a more stable power supply.

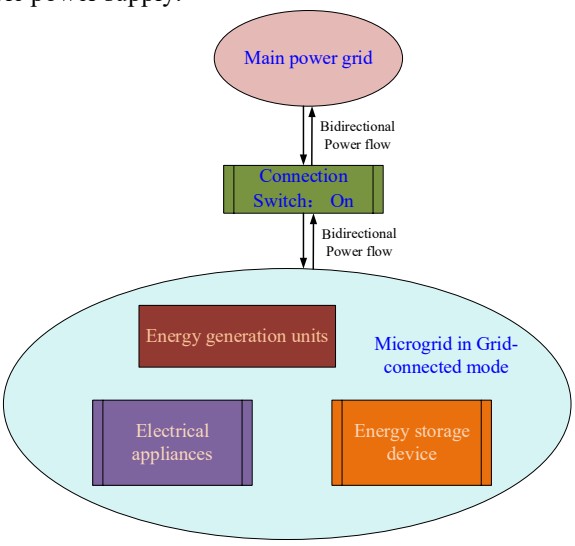


Fig. 1. The structure of microgrid in grid-connected mode.

Islanded operation: micro-grid can operate independently, which is disconnected from the main power grid. In the island operation mode, seen in Fig. 2, the micro-grid relies on its own distributed energy resources and energy storage

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equipment to meet the power demand of users. In this mode, the micro-grid can maintain independent operation when the main grid failure or disaster occurs, and provide users with reliable power supply [3].

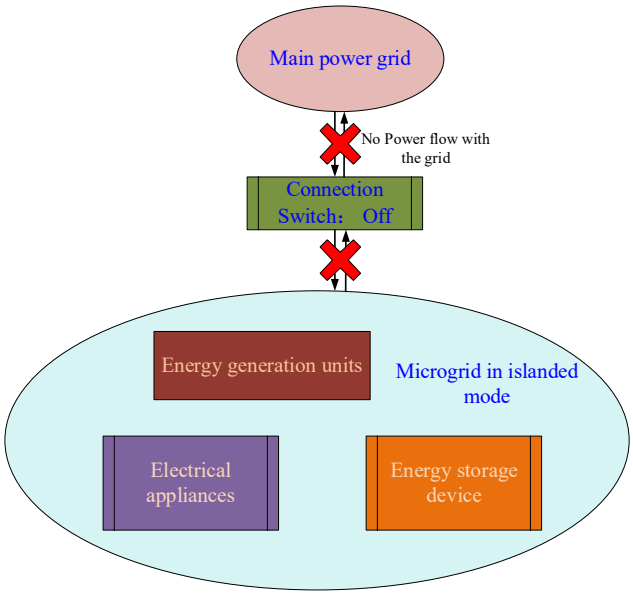


Fig. 2. Structure of microgrid in islanded mode.

Grid-connected operation and isolated island operation have different advantages under different scenarios:

(1) Grid-connected operation is suitable for normal conditions, for example, the main power supply stability is ensured. The micro-grid can make use of the power resources of the main grid to realize the diversification and complementarity of energy and improve the efficiency of energy utilization. At the same time, micro-grid can realize the income maximization through energy trade and income by selling surplus electricity to the main grid.

(2) Island operation is suitable for main power grid fault, disaster, remote area or independent power supply demand. Micro-grid can operate independently to provide reliable power supply and guarantee the basic life and production needs of users. In addition, island operation can reduce the dependence on the main power grid, improve energy security and resilience.

In addition, the grid-connected operation and island operation of the micro-grid can also be switched with each other, seen in Fig. 3, which can realize the flexible adjustment through proper control methods according to the actual situation. When the main power supply is unstable or failure occurs, the micro-grid can automatically switch to island operation mode to ensure the continuity and stability of local power supply. On the contrary, when the main power grid returns to normal power supply, the micro-grid can be switched to grid-connected operation mode again and connected with the main power grid again. To sum up, the grid-connected operation and island operation mode of micro-grid have their own advantages, can be switched according to different needs and circumstances. The summary of advantages and disadvantages is concluded in Table 1. By using these two modes flexibly, micro-grid can provide reliable and efficient power supply, reduce the dependence on the main power grid, and realize the diversification and sustainable development of energy [4].

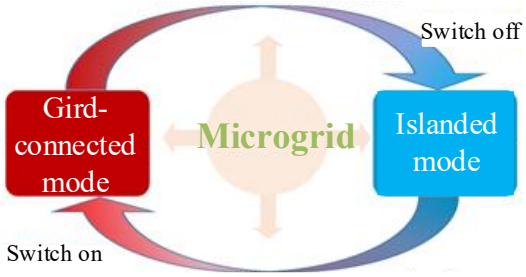


Fig. 3. The mode-switch of microgrid.

Table 1. Advantages and disadvantages of micro-gird in islanded mode/grid-connected mode.

| | Advantage | Disadvantage |
|---|---|---|
| Islanded mode | Being self-sufficient for power supply; Reducing the dependence on the main power grid | Lacks alternative power supply. |
| Grid-connected mode | Realizing the diversification and complementarity of energy; High efficiency of energy utilization; Selling surplus electricity to the main grid. | Being unstable during grid fault. |

## III. Microgrid V.S. Traditional Centralized Power System: Renewable Energy and Environmental Protection

### *A. The Basic Concept of Traditional Centralized Power System*

Centralized power system, also known as the traditional power system or the main power grid, is concentrated by large power plants to produce electricity, and transmit the electricity to the user with the transmission lines.

The following are the main features of the centralized power systems:

**(1) Large power plants:** Centralized power systems usually consist of several large power plants, these power plants use common energy resources such as coal, natural gas, nuclear energy and so on to generate electricity. These power plants are usually located far from cities or densely populated areas.

**(2) Long-distance transmission:** In order to transfer the power generated by the power plant to the user, the centralized power system needs to build a large number of transmission lines. These transmission lines are usually high-voltage transmission lines, and due to the long transmission distance, a number of substations including transformers for voltage conversion and distribution are needed to pass through.

**(3) Single energy dependence:** Centralized power systems usually rely on one or a few energy resources for power generation, such as fossil fuels, nuclear energy, etc. This results in a lower diversity of energy supply and a higher dependence on a particular source of energy.

**(4) Large-scale power supply capacity:** Because of the large scale of centralized power system, the main grid can provide large-scale power supply, which is suitable for serving a large number of users and high load demand.

**(5) Specialized operation and management:** Centralized power system needs professional operation and management team, responsible for power generation, transmission, distribution and other aspects of operation and maintenance. This requires a large number of human material and financial investment.

### *B. Comparison of Microgrids and Conventional Grids*

Microgrids differ from conventional grids in the following ways [5]:

**(1) Size:** The traditional power grid is a large-scale centralized power system, covering a wide range, can provide a large number of power supply. The micro-grid coverage is small, usually serving some small users, such as communities, industrial parks, independent islands and other areas.

**(2) Power supply:** The traditional power grid through the power grid company generation, transmission, distribution of electricity. The micro-grid through integrated distributed energy generation technology, so that a variety of energy matching with each other, independent supply of its required energy.

**(3) Energy management mode:** The traditional power network adopts the centralized control management mode, the source, consumption and distribution of energy are regulated and managed by the Power Grid Company. And the micro-grid through intelligent energy management system, automatic perception and control of supply and demand, to achieve high-precision management of energy.

**(4) Stability:** The stability of the traditional power grid is high, but there is also single-point concentration, the failure of the system reliability, recovery difficulties and so on. The micro-grid is more stable, can be in local transmission problems, self-regulation, self-supply.

**(5) Environmental protection:** The traditional power grid mostly uses the way of burning fossil fuels to generate electricity, there is greater energy consumption and environmental pollution. The micro-grid uses more renewable energy to generate electricity, less energy consumption, high degree of environmental protection.

Table 2. Comparisons between conventional girds and micro-grids

| | Conventional grids | Micro grids |
|---|---|---|
| Size | A large-scale centralized power system | Small |
| Power supply | Depends on the power grid company | Integrated distributed energy generation technology |
| Energy management mode | Adopts the centralized control management mode. | Intelligent energy management system, automatic perception and control of supply and demand. |
| Stability | High stability, but there is also single-point concentration, the failure of the system reliability, recovery difficulties | More stable, can be in local transmission problems, self-regulation, self-supply. |
| Environmental protection | Mostly uses the way of burning fossil fuels to generate electricity, there is greater energy consumption and environmental pollution | More renewable energy to generate electricity, less energy consumption, high degree of environmental protection. |

In summary, the micro-grid has the following advantages compared with the traditional power grid, which is discussed in Table 2:

(1) The micro-grid is close to the load, the line loss is significantly reduced, the construction investment and operating costs are lower.

(2) Distributed energy has many service functions, such as power generation, heating, refrigeration, and so on, which can achieve higher comprehensive utilization efficiency of energy.

(3) It is conducive to the utilization of various types of renewable energy (solar power, wind power, biomass power, etc.), reducing the total emissions, land requisition, power line corridor land and electromagnetic pollution of high-voltage transmission lines, relieving the pressure of environmental protection.

(4) It can solve part of the problem of peak shaving and backup, and adapt to the seasonal and regional changes of power demand, so that the economy and security of power system can reach the best balance.

(5) It can improve the reliability of power supply, the quality of power supply and the security of power network.

Therefore, the development of micro-grid technology can form a harmonious and diversified power grid pattern [6].

## IV. Microgrid and Renewable Energy Generation

### *A. Photovoltaic Power Generation*

A Photovoltaic (PV) power station converts solar radiation directly into direct current electricity through a photovoltaic cell module. The PV power station is connected to the grid with a power conversion device, and a power generation system that delivers both active and reactive power to the grid, generally includes photovoltaic array, controller, inverter, energy storage controller, energy storage devices. The structure of PV system is shown in Fig. 4.

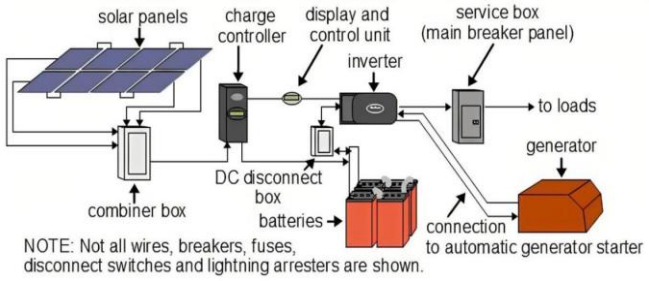


Fig. 4. The structure of the PV system.

Grid-connected PV system refers to the Direct Current (DC) power output from PV cells, which is converted into sinusoidal AC current at the same frequency and phase with the grid through grid-connected solar inverter.

The principle of photovoltaic power generation is composed of photovoltaic array of photovoltaic cells decided. Photovoltaic cells work by converting energy from the photovoltaic effect of a photovoltaic cell (also known as the photovoltaic effect), which is the photovoltaic effect of semiconductor P-N junctions. When light hits a semiconductor, photons of sunlight supply energy to electrons, which jump to higher energy bands, triggering electron-hole pairs, electrons, and holes to move toward the ends of the battery, in addition to counteracting the barrier electric field. The photogenerated electric field also makes the P-zone positively charged and the n-zone negatively

charged, forming an electromotive force between the N-zone and the p-zone, both light and non-uniform semiconductor or semiconductor and metal binding between the different parts of the potential difference. Thus, if the exterior forms a path, an electric current is generated, forming electrical energy.

According to different materials, photovoltaic cells can be divided into silicon photovoltaic cells, compound photovoltaic cells and Organic semiconductor photovoltaic cells. Silicon photovoltaic cells can be divided into crystalline silicon and amorphous silicon photovoltaic cells. Among them, crystalline silicon photovoltaic cells can be divided into monocrystalline silicon and polycrystalline silicon photovoltaic cells. At present, crystalline silicon battery is more mature and widely used. The advantages of crystalline silicon photovoltaic cells are very rich in raw materials, high reliability, relatively stable characteristics, generally can be used for more than 20 years. In terms of both energy efficiency and lifetime, the single-crystal silicon photovoltaic cells have the highest conversion efficiency in silicon-based photovoltaic cells, with a theoretical conversion efficiency of 24% to 26%, the conversion efficiency of polysilicon is slightly lower, the theoretical value of conversion efficiency is 20%, but the price is cheaper; At present, the conversion efficiency of monocrystalline silicon battery is 16%~18%, and polycrystalline silicon battery is 12%~14%. A thin-film battery with multi-layer and multi-p-n junction can achieve 40%~50% photoelectric conversion efficiency. The basic principle is to lay a thin layer of photoelectric material on a non-silicon substrate, the silicon semiconductor consumption of the photoelectric material is greatly reduced, and the cost of the photovoltaic cell is reduced. The silicon thin film photovoltaic cell has a more sustainable development prospect because of its abundant raw materials, non-toxic and non-pollution.

### B. *Wind Energy Generation*

Wind power generation converts the kinetic energy of the wind into mechanical kinetic energy, and then into electrical energy. The principle of wind power generation is to use the wind to drive the blades of the windmill to rotate, and then through the speed-increasing machine will increase the speed of rotation, to promote the generator to generate electricity. The structure of wind energy generation is shown in Fig. 5 and the diagram of wind energy generation machine with power converters is shown in Fig. 6.

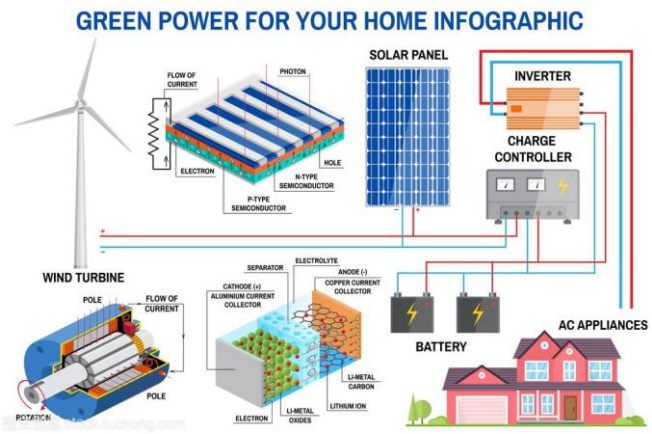


Fig. 5. The structure of wind energy generation.

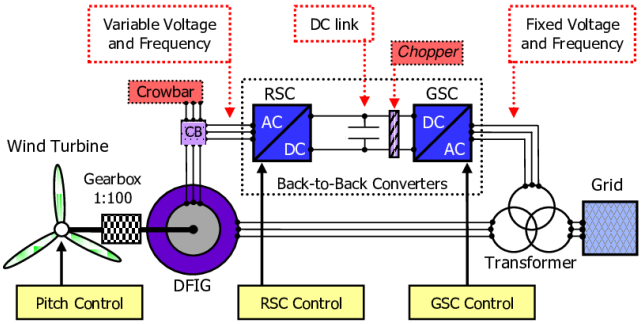


Fig. 6. The diagram of wind energy generation machine with power converters.

With current Windmill Technology, a breeze speed of about three meters per second (degree of Breeze) can start generating electricity. Wind power is becoming a worldwide craze because it uses no fuel and produces no radiation or air pollution. The devices needed for wind power generation are called wind turbines. The wind turbine can be divided into three parts: wind turbine (including tail rudder), generator and iron tower. (large wind farms generally have no tail rudders, and only small (including domestic) ones.) [1].

Wind turbines, which convert kinetic energy from wind to mechanical energy, consist of two (or more) propeller-shaped impellers. When the wind blows to the blade, the blade produces aerodynamic drive wind wheel rotation. Blades are made of high-strength, light-weight materials and are made of fiberglass or other composite materials, such as carbon fiber. Now there are also some vertical wind turbines, S-type rotating blades, etc., which also function as normal propeller-type blades.

The use of wind turbines, is to keep the wind energy into our household use of the standard market electricity, the extent of the savings is obvious, a household electricity a year only 20 yuan battery fluid price. Today's wind turbines are much better than they were a few years ago, when they were only used in a few remote areas. Wind turbines use electricity directly from a 15-watt bulb, dimming the light and damaging the bulb frequently. Now, due to the technical progress, using Advanced Charger, inverter, wind power has become a certain amount of technology content of the small system, and can replace the normal market electricity under certain conditions.

### C. *Energy Storage Battery System*

The principle of energy storage battery is through chemical reactions to convert electrical energy into chemical energy, and can also convert chemical energy into electrical energy when needed. The battery consists of two electrodes (positive and negative) and an electrolyte. The positive and negative electrodes are separated by an electrolyte, but allow ions to move between the two electrodes. When the battery is in a charging state, an external power supply will pass current through the battery, so that the positive electrode oxidation reaction, the negative electrode reduction reaction, the electrical energy into chemical energy, stored in the battery.

When an energy storage battery is used to release electrical energy, an electrochemical reaction is formed between the positive and negative electrodes of the battery, and the chemical energy is converted into electrical energy. The positive electrode undergoes a reduction reaction and the

negative electrode an oxidation reaction. The ions move in the electrolyte to form a current output. The working principle of energy storage battery is based on different chemical reaction mechanism. Common energy storage batteries include lead-acid batteries, lithium-ion battery batteries and sodium ion batteries. Each cell has different electrode materials and electrolytes, as well as specific chemical reaction mechanisms to achieve the storage and release of electrical energy. The structure of the energy storage battery system is shown in Fig. 7.

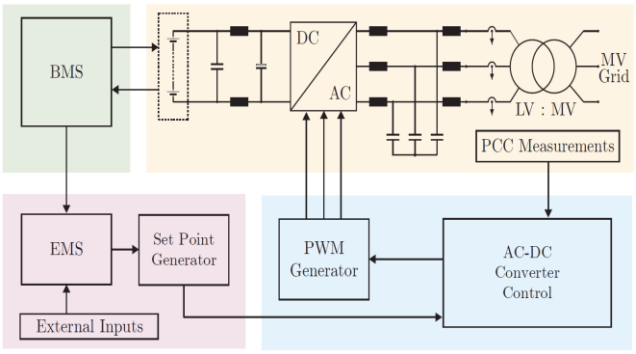


Fig. 7. The structure of the energy storage system.

The role of energy-storage batteries in the micro-grid includes the following aspects:

(1) Balancing renewable energy supply and load in islanded mode: When the micro-grid is operating on an isolated island, the generation of wind and new energy is affected by the external environment. (For example, photovoltaic power cannot be generated at night.) At this time, if only new energy is used to generate electricity, it is difficult to meet the load demand. As a result, energy storage can help balance new energy generation with electricity demand. When the new energy generation is insufficient, the stored energy will compensate for the additional energy required by the load.

(2) Balancing grid load: When the microgrid is connected with the main grid, energy-storage batteries can release stored energy during peak load, store excess energy during low load, to balance the load of the power grid and improve the stability and reliability of the power grid.

(3) Adjustment the grid frequency: Energy storage battery can change according to the grid frequency, timely adjust the battery charge and discharge state, to maintain the stability of the grid frequency. When the grid frequency is high, the battery can absorb excess energy to charge; when the grid frequency is low, the battery can release stored energy to discharge, to regulate the grid frequency.

(4) Dealing with grid fault: When the micro-grid is disconnected from the main grid, the battery can provide backup power to ensure the normal operation of the micro-grid. Energy storage battery can be switched to independent power supply mode when power grid failure, and provide stable power supply for micro-grid.

(5) Improving the efficiency of the renewable energy: Storage cells can store electricity from unstable renewable sources, such as solar and wind, for release when needed. This will increase the use of renewable energy and reduce reliance on traditional energy sources. In short, the role of energy storage battery in the micro-grid is to improve the stability and reliability of the grid, regulate the load and frequency of the grid to cope with grid failures, and improve the utilization of renewable energy.

Besides, all of them need power electronics to realize energy conversion. For example, photovoltaic power needs DC/DC, DC/AC converters, wind power needs AC/DC, DC/AC converters, and energy storage systems need bi-directional DC/AC converters. Therefore, the development of power electronics technology is also important to microgrids [7].

## V. Why Are the Microgrids Deemed to Provide Green and Clean Energy ?

The power generation units in the micro-grid are mainly composed of new energy renewable energy generation such as photovoltaic power generation and wind power generation, and so on. The renewable energy generation does not generate additional carbon emissions in the production of electricity, nor does it produce harmful substances such as sulfides [8]. Here is an example to illustrate the advantages of renewable energy generation in reducing carbon emissions and protecting the environment.

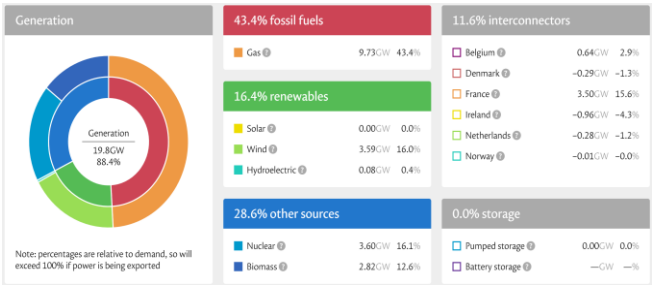


Fig. 8. Diagram of National Grid: live at 9:55 am [9].

Fig. 8 shows the generation composition in the network operated by National Grid UK at 9:55pm, 14th, July 2023.

As is seen in the Figure, the total carbon footprint of the National Grid in an hour is 185g/kWh. If all the electricity is generated by the fossil fuels, the total carbon footprint should be 450g/kWh. Furthermore, if the 41.1% fossil fuels of the total generation were subtracted by 20% to 21.1% and replaced by renewable energy sources, the total carbon emissions per hour can be calculated as 94.9g/kWh. More deeply, if all fossil fuels were replaced by the renewable energy sources, the total carbon emissions per hour should be eliminated to 0g/kWh.

This real-life example clearly shows the environmental advantages of the micro-grid and renewable energy sources. It does not need fossil fuel to generate electricity and does not have any extra carbon emissions.

Moreover, Micro-grid is characterized by the use of local power generation, there is no need to build long-distance transmission lines, so on the one hand to reduce construction costs, on the other hand, to reduce power loss on long-distance transmission lines.

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## VI. Negative Effects of the Micro-grid: Does Micro-grid Benefit the Environment and Human Society at any Aspect?

Electromagnetic pollution refers to the phenomenon that the electromagnetic radiation produced by human activities is beyond the normal range, causing adverse effects on human health and the environment.

The disadvantages of electromagnetic pollution are mainly manifested in the following aspects:

(1) The impact on human health: Long-term exposure to high-intensity electromagnetic radiation may lead to a series of health problems, include headache, insomnia, fatigue, lack of concentration, memory loss, etc.. Some studies have also found a link between electromagnetic radiation and cancer, reproductive health problems and neurological disorder.

(2) Damage to the ecosystem: Electromagnetic Radiation has a certain impact on the growth and reproduction of plants and animals. Some studies have suggested that electromagnetic radiation may lead to disruption of bird migration and seasonal behavior, affecting bees and other pollinating insects, thus affecting the balance and stability of ecosystems.

(3) Interference with wireless communications and equipment: Electromagnetic contamination may interfere with wireless communications and other electronic equipment, affecting their normal operation. For example, electromagnetic radiation can interfere with cell phone signals, slow wireless networks, and make electronic devices unstable.

(4) Electromagnetic radiation leakage risk: High-intensity electromagnetic radiation leakage may cause safety risks to personnel and equipment. Living near a high-voltage transmission line, for example, can be exposed to high levels of electricity.

Although the micro-grid has many advantages in the treatment of electromagnetic pollution, the electronic environment needed by the micro-grid may cause more serious electromagnetic pollution instead, for example, a large number of systems to be controlled lead to a more complex current environment and more electrical work.

## VII. The Future Trends of Micro-grid

The future of the micro-grid is very promising [10]. Here are some possible trends:

(1) With the increasing the proportion of renewable energy, the micro-grid will integrate more renewable energy resources such as solar, wind and hydropower to reduce reliance on traditional energy sources and achieve a cleaner and sustainable energy supply.

(2) Application of Intelligent Energy Management System: With the development of Internet of things and artificial intelligence, micro-grid will be more intelligent. The Intelligent Energy Management System can monitor and optimize the production, storage and consumption of energy in real time, and make flexible dispatch according to the demand and supply, so as to improve the efficiency of energy utilization and the stability of the system.

(3) Combination of micro-grid and electric vehicle charging pile: With the popularization of electric vehicles, micro-grid can be combined with electric vehicle charging pile to achieve two-way flow of energy. Electric vehicles could be used as mobile energy storage devices to store excess electricity, or to power micro-grids when needed, improving energy efficiency and flexibility.

(4) Interconnection of multi-micro-grids: Micro-grid can be connected with the traditional grid through interconnection, to achieve the two-way flow of energy. In this way, the energy can be shared and optimized in the micro-grid, and the surplus energy can also be transferred to the traditional grid, providing greater flexibility and reliability for the whole energy system.

(5) Application of microgrids in rural and remote areas: Micro-grid can provide a reliable supply of electricity to rural and remote areas and address the problem of the inability to be covered by traditional grids. By using the internet to connect all microgrids controller.

## VIII. Conclusion

Energy in modern society is changing. The proportion of renewable energy, such as solar and wind power, is increasing gradually. Distributed power supply has the advantages of small investment, environmental protection and high flexibility. But the randomness and fluctuation of distributed power supply are uncontrollable, and the large-scale application and access also bring great challenge and impact to the traditional power grid. The introduction of micro-grid realizes the flexible, large number and diversity of distributed power supply. It is an effective way to realize the active distribution network to realize the reliable supply of various load energy forms, which makes the transition from the traditional grid to the smart grid.

Micro-grid is a small power generation and distribution system, which is composed of distributed power supply (renewable energy source), energy storage device, energy conversion device, load, monitoring and protection device. The contribution of our work in this paper can be concluded as follows:

In this paper, the microgrid to the modern society is described in detail. And the microgrid is compare with the traditional grid for the environmental protection benefits. This paper also explains the significance of renewable energy for the micro-grid and the basic structure of renewable energy technology in detail, such solar energy and wind energy. While seeing the benefits of microgrid and analyzing its benefits through actual cases, we also analyzed the possible harm of microgrid and analyzed its severity.

## Conflict of Interest

The author declares no conflict of interest.

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